

Articles

Alpine Skiing Injuries A Nine-Year Study

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Injury patterns in alpine skiing have changed over time as ski, boot, binding, and slope-grooming technologies have evolved. We retrospectively examined injury patterns in alpine skiers over a 9-year period at the Mammoth and June mountains (California) ski area. A total of 24,340 injuries were reported for the 9 seasons studied, and total lift tickets sold numbered 9,201,486. The overall injury rate was 2.6 injuries per 1,000 skier days and increased slowly over the period studied. The knee was the most frequently injured area at 35% of all injuries. Increasing trends ($P < .05$) were noted for the rates of lower extremity injuries (37%) and knee injuries (45%). A decreasing trend was noted for the rate of lacerations (31% decrease). Slight increases were noted in upper extremity and axial injury rates. Skiing injuries continue to be a worrisome recreational problem despite improvements in ski equipment and slope-grooming techniques. The increasing trend in lower extremity, particularly knee, injury rates highlights the need for continued skier education and equipment innovation.

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The sport of alpine skiing has grown dramatically in the United States from an estimated 10,000 participants in 1935 to 14.5 million in 1987.¹ Injury rates and patterns have been extensively studied both in this country and abroad and have shown a significant decrease from the range of 7.6 to 10.9 injuries per 1,000 skier days^{2,3} in the late 1950s and 1960s to current estimates of 0.9 to 6.0 injuries per 1,000 skier days.⁴⁻⁸ It is suggested that changes in ski equipment (skis, bindings, boots, and poles) and modern slope-grooming techniques have led to this reduction in the overall injury rate,⁷ specifically leading to reduced injury rates for ankle sprains, ankle fractures, and spiral tibial fractures.^{1-3,5,6,8-11}

Certain injury types have not shown reductions, however, with injuries to knee ligaments being the most important exception. The knee has been reported as the most common site of injury, accounting for 20% to 27% of all skiing injuries ("Bringing Skiers to Their Knees," *Snow Country*, 1993 March-April, pp 70-74).^{1,4,7,8,10-13} The incidence of knee injuries has shown little or no decrease through the years,^{2,5,6,8} and a recent study from Australia reported an increasing incidence of knee injuries.³ Over the past 30 years, little change has been noted in upper extremity injury rates, including the skier's thumb.^{2,3,5,6,8,14-17}

In this study, we examine ski injury patterns at a major western ski resort over a nine-year period (1983 to 1992).

Patients and Methods

Mammoth-June, in the eastern Sierra mountains of California, is one of the largest ski resort areas in North

America. The ski patrol first-aid rooms at the base of each mountain provide first-aid care and triage for all skiers injured at both resorts. Since the 1983-1984 winter season at Mammoth and the 1986-1987 season at June, injuries reported by the ski patrol and first-aid room staff have been recorded on a computer database. Accident information recorded by the patrol includes injury zone, injury type, and general information such as age, sex, and skier ability. One of us (T.M.D.) has been a member of the Mammoth-June Ski Patrol since 1963 and participated in the study design and data analysis. Physician evaluation is not available on site. Skiers self-triage to several sites, and physicians' diagnoses are not available.

We examined the incident-report database from Mammoth-June for all recorded skiing injuries from the 1983-1984 through the 1991-1992 winter seasons. Specific injury rates were calculated by dividing the number of injuries for a particular season by the number of skier days in that season and multiplying by 1,000. This yields the standard method of reporting skiing injury rates: injuries per 1,000 skier days. Skier days are represented by lift ticket sales at the resort, with one ticket equaling one skier day. We can anticipate a small underestimation error in this calculation because skiers with employee or season passes are not counted in the total skier days. Conversely, snowboarders were excluded from the count of injured skiers and may represent as many as 5% of lift ticket sales beginning with the 1989-1990 season when they were first invited to the Mammoth Mountain Ski Area.

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TABLE 1.—*Demographics of Skiers Injured at Mammoth-June (California) Ski Resorts Over a 9-Year Period*

Characteristic	1983 to 1992
Total injuries, No.....	24,340
Mean age (SD), years	27.9 (13.5)
Sex	
Male, %	50
Female, %	50
Ability	
Beginner, %	19
Low intermediate, %	13
Intermediate, %	43
Advanced, %	18
Expert, %	4
Racer, %	2

SD = standard deviation

Statistical analysis was performed by linear regression. The level of significance to reject the null hypothesis was set at less than .05.

Results

Demographics

From 1983-1984 through 1991-1992, a total of 24,340 injuries were reported by the Mammoth-June Ski Patrol. During this same time period, 9,201,486 lift tickets were sold. Table 1 presents the mean age, sex, and ability levels of those injured over the nine-year period. There were no significant trends for sex or ability level over the nine years. Figure 1 shows that the age of those injured increased 11% over the nine-year period (26.5 years to 30.25 years, $R^2 = .83$, $P < .01$).

Trends in Overall Injury Rate

The overall injury rate over the nine-year period, shown in Figure 2, was 2.6 injuries per 1,000 skier days. The overall injury rate increased 59%, from 1.9 injuries per 1,000 skier days in 1983-1984 to 3.0 in 1991-1992 ($R^2 = .76$, $P < .01$).

Most Frequent Injury Zones

Lower extremity injuries accounted for 54% of all injuries. Injuries involving the axial skeleton (head, neck, chest, back, trunk, and pelvis) accounted for 21% of all injuries, and upper extremity injuries represented 19% of all injuries.

The area most frequently injured was the knee, accounting for 35% of all injuries. The next most frequently injured area was the head and face at 15%. Shoulder injuries were the most common upper extremity injury at 8%. Thumb injuries were the second most common upper extremity injury at 4%. The number of injuries for each injury zone is shown in Table 2.

Trends in Injury Rate for Specific Regions

Upper extremity injuries showed a significant increase in the rate of 53% from 0.38 injuries to 0.54 injuries per 1,000 skier days over the nine years ($R^2 = .46$, $P < .05$) (Table 3). Within the subset of upper extremity

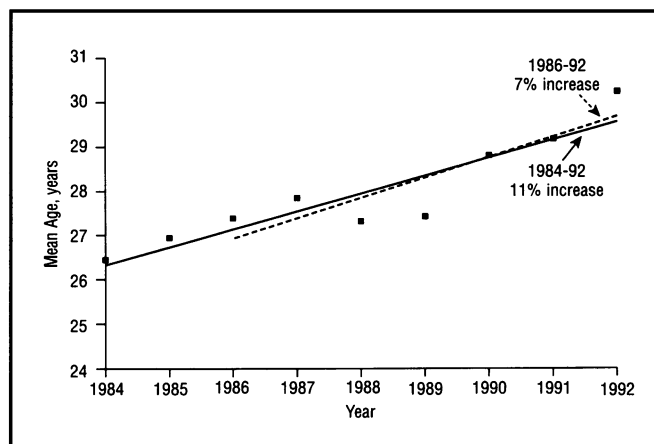


Figure 1.—The graph shows the mean age versus the year of the study. Linear regression lines for the 9-year period are shown. A significant increase of 11% ($R^2 = .83$, $P < .01$) in the mean age of injured skiers was noted.

injuries, thumb and wrist injury rates both increased (66%, $R^2 = .45$, $P < .05$, and 94%, $R^2 = .57$, $P < .05$, respectively).

Axial skeleton injuries showed a similar pattern, with the total number of axial skeleton injuries—head, clavicle, chest, rib, back, and pelvis—all showing significant ($P < .05$) increases for the nine-year period.

The total number of lower extremity injuries showed a significant increasing trend (60% increase, $R^2 = .86$, $P < .01$). Over the nine-year period, the number of knee injuries showed a 92% increase ($R^2 = .88$, $P < .01$). The rates for sprains and fractures are shown in Figure 3.

Ability Level and Knee Sprains

We compared the ability level with the incidence of knee sprains. Skiers who classified themselves as beginners or low intermediates sustained 25% and 18%, respectively, of the total number of knee sprains, while only sustaining 19% and 13%, respectively, of the total number of injuries. Intermediate skiers received 41% of all knee sprains and 42% of all injuries. Skiers who

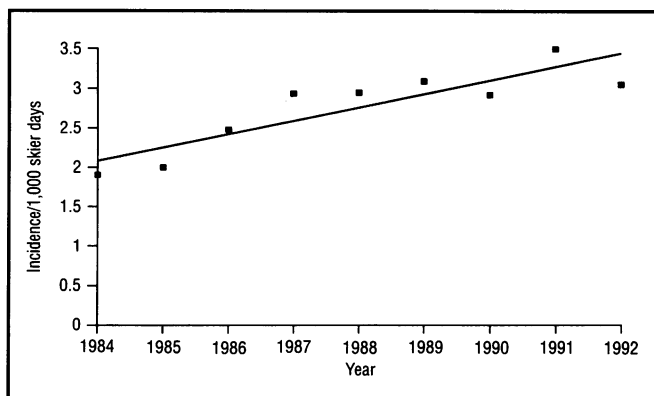


Figure 2.—The trend in the overall injury rate is shown. Over the 9-year period of the study, linear regression analysis showed a significant increase in the overall injury rate of 59% ($R^2 = .76$, $P < .01$).

TABLE 2.—Number of Injuries for All Injury Zones, 1983 to 1992

Injury Zone	1983-1984	1984-1985	1985-1986	1986-1987	1987-1988	1988-1989	1989-1990	1990-1991	1991-1992	Total
Upper extremity										
Shoulder.....	219	184	276	165	297	259	222	97	196	1,915
Arm.....	76	56	95	70	63	73	61	31	76	601
Elbow.....	27	13	31	14	28	17	13	4	14	161
Wrist.....	43	42	68	34	84	73	64	34	49	491
Hand.....	46	48	83	49	59	46	31	23	27	412
Thumb.....	87	93	173	111	118	129	120	96	116	1,043
Subtotal.....	498	436	726	443	649	597	511	285	478	4,623
Lower extremity										
Hip.....	20	37	50	33	46	49	36	15	39	325
Thigh.....	69	53	62	32	70	47	2	4	8	347
Knee.....	771	777	1,127	660	1,046	1,142	1,037	588	1,008	8,156
Leg.....	262	306	316	176	246	291	246	129	252	2,224
Ankle.....	223	155	194	106	205	172	141	77	168	1,441
Foot.....	10	8	13	9	7	11	3	2	2	65
Subtotal.....	1,355	1,336	1,762	1,016	1,620	1,712	1,465	815	1,477	12,558
Head.....	249	233	292	194	267	260	306	135	251	2,187
Spine										
Neck.....	21	24	40	34	46	43	26	13	33	280
Back.....	70	63	74	60	99	74	73	53	80	646
Pelvis.....	1	2	1	1	2	3	2	1	5	18
Subtotal.....	92	89	115	95	147	120	101	67	118	944
Other										
Clavicle.....	4	24	23	11	20	28	15	14	32	171
Face.....	178	139	280	144	252	205	137	84	98	1,517
Internal.....	63	107	157	111	166	169	138	58	126	1,095
Rib.....	27	29	42	16	35	49	42	22	26	288
Chest.....	1	8	8	4	7	9	7	6	7	57
Teeth.....	1	4	7	2	8	0	1	2	2	27
Multiple.....	10	74	185	39	85	61	104	25	40	623
Other.....	22	24	18	18	19	44	35	23	47	250
Subtotal.....	306	409	720	345	592	565	479	234	378	4,028
Total.....	2,500	2,503	3,615	2,093	3,275	3,254	2,862	1,536	2,702	24,340

rated themselves as advanced and above sustained 16% of knee sprains and 24% of all injuries. We have no information about the ability levels of those who were not injured.

Discussion

The overall injury rate for the nine years, 2.7 injuries per 1,000 skier days, is consistent with rates found in the United States, Australia, and Europe.²⁸ Unlike previous studies that show a decreasing trend in the overall injury rate,^{2,3,5,6,8} we found a small increase over the nine-year period.

The overall injury rate and the three subsets of axial, lower extremity, and upper extremity injuries all had rates that increased significantly over the nine years of the study from 1983-1984 through 1991-1992. The reasons this might occur include an increased number of beginning skiers, poorer physical conditioning, improved slope grooming with a resultant firmer snow surface, more skiers leading to crowding on the ski slopes, and increasing skiers' age. There are also reasons to predict decreasing accident rates, specifically improvements in equipment, binding-adjustment practices, and slope-grooming practices; the presence of wider and safer slopes; and an increase in ski school availability and instruction.

The increased injury rate, although statistically significant, is small and may be explained by several factors. With improved risk management practices, there is a trend to report virtually all skier-patrol encounters, so that even mild "ski yourself down the hill" injuries are more likely to have an accident report completed. A new first-aid program called Winter Emergency Care sponsored by the National Ski Patrol Association replaced the National Red Cross's Advanced First-Aid Program in 1988. With increasing knowledge and improved evaluation skills, ski patrol staff are more likely to make and record suspected diagnoses. In today's litigious world, the thresholds for diagnosis and first-aid treatment are raised.

The study is certainly flawed by the lack of physician diagnosis. The patrollers are well trained but, lacking x-ray films and physician examination skills, are required to "overdiagnose." If a skier falls and complains of knee pain sufficient to require a leg splint and a toboggan ride off the ski slope, the patrol staff diagnoses a presumed knee sprain. The severity of the injury is not graded. If a skier falls and injures the midportion of the lower leg, the patrol staff diagnoses a presumed lower leg fracture.

It is the senior author's opinion that the site of injury is correctly diagnosed 100% of the time. Because all

TABLE 3.—Trends in Injury Rates for All Injury Zones Using Linear Regression Analysis for the Full 9-Year Study Period

Injury Rate* Injury Zone	Linear Regression Statistics†			
	1983	1992	% Change	R ²
Overall	1.91	3.04	64	0.76‡
Upper extremity				
Shoulder	0.62	0.22	39	0.39
Arm	0.06	0.09	35	0.19
Elbow	0.02	0.02	-29	0.14
Wrist	0.03	0.06	99	0.57§
Hand	0.04	0.03	-15	0.04
Thumb	0.07	0.13	115	0.45§
Total	0.38	0.54	48	0.46§
Lower extremity				
Hip	0.02	0.04	64	0.37
Thigh	0.05	0.01	-82	0.55§
Knee	0.89	1.13	111	0.88‡
Leg	0.20	0.28	36	0.68‡
Ankle	0.17	0.19	25	0.27
Foot	0.01	0.00	-57	0.30
Total	1.04	1.66	71	0.86‡
Axial skeleton				
Head	0.19	0.28	66	0.76‡
Face	0.14	0.11	2	0
Teeth	0.001	0.002	-2	0
Neck	0.02	0.04	57	0.21
Clavicle	0.00	0.04	294	0.68‡
Chest	0.001	0.008	242	0.58§
Rib	0.02	0.03	102	0.48§
Back	0.05	0.09	104	0.60§
Pelvis	0.001	0.006	835	0.62§
Total	0.42	0.60	54	0.59§
Other				
Multiple injuries	0.01	0.04	23	0.02
Internal injuries	0.05	0.14	90	0.51§
Other	0.02	0.05	411	0.79‡

*Injury rate is presented as number of injuries per 1,000 skier days.

†Linear regression was performed for the full 9-year period, with the percentage of change calculated from regression estimates.

‡P < .01.

§P < .05.

injuries require the more serious diagnoses to avoid the legal risk of misdiagnosis and mistreatment, the severity of an injury is always conservatively graded. Extremity injuries are accurately diagnosed. Spine injuries are always diagnosed if any suspicion of injury exists.

The raw data show a statistically significant (albeit small) increase in skiing accident rates. Viewed from a larger perspective, the skiing accident rate in this large study is between 2.0 and 3.0 accidents per 1,000 skier days. Based on these facts, we suggest that the overall injury rate for alpine skiers at Mammoth-June in the late 1980s and early 1990s is around 2.6 to 3.0 per 1,000 skier days, a finding that has been echoed recently at an Australian resort.³ This suggests that despite improvements in slope grooming and snowmaking at Mammoth-June resorts, as well as changes in ski equipment technology, no reduction in overall skier injury rate has been noted in the period from 1983 to 1992.

Perhaps the most worrisome observation in this study is the upward trend in the incidence of lower extremity injuries. Unlike the findings in other reports of decreas-

ing trends in the incidence of lower extremity injuries,^{2,3,5,6,8} there was a significant increase in the number of lower extremity injuries over the nine years of the study. Johnson has clearly shown in several studies that the incidence of injuries to the lower extremity caused by twisting moments—using the *Random House Dictionary* definition of “moment” as a tendency to produce motion especially about an axis—have substantially decreased over the years due to improvements in binding design and a higher percentage of properly set binding-release torques.^{1,5,6,8} Johnson and others have also reported that the incidence of knee injuries has not decreased substantially over the past 30 years.^{1,6,8} One worker has recently shown an increasing rate of injuries caused by bending moments in the lower extremity.³ Similar results were noted in this study, with the rate of injuries to feet and ankles showing no increase or a decrease, whereas the incidence of knee injuries increased. This points to what others have suggested, namely that ski equipment design has effectively evolved to protect against the classic skiing injuries: spiral fractures of the tibia and fractures and sprains in the ankle, while having less success at reducing bending and twisting forces farther up the leg.^{2,3,5,9-11} Alternatively, with the ankles and lower legs better protected, injuries may be transferred to the next most vulnerable area, namely the knees.

Others have noted that whereas the rate of most skiing injuries is declining, the rate of knee injuries has either remained unchanged since as far back as the 1960s or has increased.^{1,2,5,6,8} It has been suggested that these findings are related to both greater boot-top height, which transfers bending and twisting forces upward to the knees, and a lack of binding designs that respond to the bending and torsional forces that are transferred to the knees (*Snow Country* 1993 March-April, pp 70-74).^{1-3,5,9-11} This study supports these findings.

The incidence of thumb injuries showed a slight but significantly increasing trend in this study. This agrees with previous findings that it remains the site of the first or second most common upper extremity injury.^{2,3,5-8} The mechanism of injury for the most common hand injury,

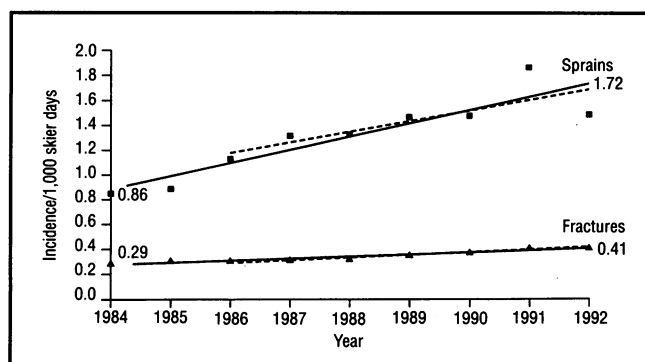


Figure 3.—Trends in the rates of sprains and fractures are shown. The fracture rate is stable. The rate of sprains (predominantly of knees) is rising and presumably accounts for much of today's skiing injury rates.

“skier’s thumb,” involves a fall with the abducted thumb hitting the snow while the ski pole grip acts as a lever to stretch or tear the ulnar collateral ligament.^{14,15} Changes in the design of ski pole handles, including the strapless pole, have not lessened the rate of injury and in some instances have been shown to increase the risk of injury.^{16,17} Further investigation into skier’s thumb injuries and ski pole design is needed.

The decrease in the number of lacerations over the study period coincides with the use of ski brakes and the discontinuation of safety straps. Presumably falling skiers, without safety straps, are less likely to strike and be cut by their own skis. This decrease in the rate of lacerations has been reported by others.^{3,6}

A curious finding in this study relates to the increasing age of injured alpine skiers. This increase was most pronounced for the final four years of the study, when the mean age of those injured went from 27.4 years during the 1988-1989 season to 30.2 years during the 1991-1992 season, an increase of greater than 2% per year. Because we do not know the demographics of all who purchase ski tickets, we can only speculate that this change relates to the introduction of snowboarding at Mammoth Mountain. Snowboarders were first invited during the 1988-1989 season and have grown to account for an estimated 5% of the slope users by the end of the 1991-1992 season. Snowboarder participants are younger and have been shown to have a lower mean age of injured participants than alpine skiers.¹⁸⁻²⁰ Thus, we believe that the trend of increasing age of injured alpine skiers may reflect the growing popularity of snowboarding among younger participants who have turned from skiing to snowboarding or that skiers really are increasing in age, perhaps because fewer children or young adults are skiing. We favor the snowboard explanation.

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